



Short communication

Effects of marine atmosphere on the cell performance in molten carbonate fuel cells

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HIGHLIGHTS

- Cell performance is increased with increasing impregnated NaCl amount in cathode.
- Accumulated Na^+ ion gives positive effect on cell performance.
- HCl doesn't cause severe corrosion because emitted HCl level is below 1 ppm.

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ABSTRACT

The effects of NaCl, a main component in seawater, on molten carbonate fuel cell (MCFC) performance is investigated using a single cell test with 1, 5, and 10 wt.% NaCl-impregnated cathodes for marine applications. The cell performance increases with increasing amounts of impregnated NaCl in the cathode. This cell performance enhancement is due to the reduction in the charge transfer resistance of the electrode. From the analysis of the electrolyte composition using the inductively coupled plasma (ICP) and ion chromatography (IC) methods after cell operation, it is confirmed that the Na^+ ions are accumulated in the carbonate melts, and approximately 80 at.% of the Cl⁻ ions are emitted into the anode outlet as HCl. Expecting that the emitted HCl causes severe corrosion of the utilities, the concentrations of accumulated Na^+ ions of emitted HCl in the anode outlet are calculated when air with a sea-salt particle concentration of 5–500 $\mu\text{g m}^{-3}$ is supplied to the MCFC stack. Although HCl is a very corrosive gas, it is expected that the emitted HCl does not cause severe corrosion because, even at a high sea-salt concentration of 500 $\mu\text{g m}^{-3}$, the emitted HCl concentration is low enough to operate the stack safely.

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1. Introduction

Marine transport accounts for only 3% of global petroleum consumption but contributes 14% of the NO_x and 16% of the SO_x global emissions due to diesel being used as fuel [1]. Currently, the marine industry is under pressure to reduce emissions and become more environmentally friendly. Thus, the marine industry has focused on the use of fuel cells (FCs) as auxiliary power units (APUs) because fuel cells can provide several advantages over diesel, such as low emission levels, high efficiency, and silent and vibration-free electricity generation [2,3]. Fuel cells convert the chemical energy of a gaseous or gasified fuel directly into electricity via electrochemical reactions and, therefore, unlike conventional thermal engines, are not limited by Carnot efficiency.

It is known that the typical required power of a fuel cell stack ranges from 250 kW up to several MWs for marine applications [1]. Among the currently available fuel cell technologies, molten carbonate fuel cells (MCFCs) and polymer electrolyte membrane fuel cells (PEMFCs) are considered the most promising candidates for marine applications. Additionally, solid oxide fuel cells (SOFCs) have, in theory, the highest potential but are currently not sufficiently developed for applications. Although the MCFC start-up process takes longer than that for PEMFCs [4], the marine application of MCFCs is actively studied in many countries because MCFCs operate at a high temperature with a high tolerance to air-contamination and carbon monoxide, a contaminant found in fuel [5].

For marine applications of MCFCs as APUs, the inflow of new impurities into the MCFC stack has to be considered because, in a marine atmosphere, seawater mists can be introduced into the cathode side via air, which is one of the reactant gases [6]. Table 1 shows the general seawater composition [7]. As shown in Table 1,

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Table 1
Composition of generic seawater [7].

Elements	Composition (%)
Cl	1.937
Na	1.077
SO ₄	0.271
Mg	0.130
Ca	0.041
K	0.039
CO ₃	0.002
Br	0.007
Total	3.504

Cl[−], Na⁺, SO₄^{2−}, Mg²⁺, Ca²⁺, K⁺, and CO₃^{2−} are major components of seawater. Of the above-mentioned components, it is expected that Mg²⁺, Ca²⁺, K⁺, and CO₃^{2−} produce no negative effects on the cell performance of MCFC stacks. Because K⁺ and CO₃^{2−} ions are the main components of a MCFC electrolyte, these components are dissolved in the carbonate melts if they enter the MCFC stacks. It is expected that Mg²⁺ and Ca²⁺ have positive effects on the cell performance of MCFC stacks. Mg²⁺ is added to the cathode intentionally to reduce Ni dissolution in the carbonate melts because this dissolution causes short-circuiting during long-term operation [8]. According to Frangini and Scaccia [9], the addition of small amounts of Ca²⁺ to carbonate melts enhances the O₂ solubility of the melts and improves the oxygen reduction reaction (ORR), which is an electrochemical reaction on the cathode side that enhances cell performance. By contrast, the SO₄^{2−} impurity in seawater produces a negative effect on the cell performance. According to the report by Watanabe et al. on exposing MCFC stacks to impurities [10], exposure of only 1 ppm SO₂ decreased the cell performance of a 1 kW stack, largely due to the sulfur poisoning effect.

Although several articles expected that a NaCl impurity would produce a negative effect on an MCFC stack [1,5,11–13], there are no reports that experimentally show the effects of a NaCl impurity on the cell performance of MCFCs. As shown in Table 1, NaCl is a main component of seawater. Thus, the study of this NaCl effect is important for marine applications. In this study, the NaCl effect on the cell performance of MCFCs is examined. Because NaCl exists as a solid due to its high melting point (800 °C), it is difficult to continuously introduce NaCl into the cathode side using air. Therefore, a NaCl-impregnated cathode was prepared, and its electrochemical performance was examined using a single cell test. Although it is difficult to simulate the real conditions of a marine atmosphere exactly, it is thought that the single cell test using a NaCl-impregnated cathode can give basic information on the NaCl effect on cell performance. From the experimental results of this test, the NaCl effect during MCFC stack operation in a marine atmosphere is inferred.

2. Experiment

To examine the NaCl effect on cell performance, 1, 5, and 10 wt.% NaCl-impregnated cathodes were fabricated by dip-coating a porous Ni plate into a NaCl aqueous solution. The amount of impregnated NaCl is controlled by varying the concentration of the NaCl aqueous solution. The NaCl-impregnated Ni plate was dried in an oven at 80 °C for 1 h.

The electrode performances of the NaCl-impregnated cathodes and a pure cathode were evaluated using a single cell with an active electrode area of 100 cm². Except for the cathodes, the conventional components, such as the Ni–Al anode, Li/K carbonate electrolyte, and Al fiber reinforced LiAlO₂ matrix, were identical for the single cell experiments. The single cells were operated at 620 °C. The gas compositions in the cathode and anode were Air:CO₂ = 7:3 and

H₂:H₂O:CO₂ = 72:18:10, respectively. A DC current was applied to the single cells using an electric loader (ELTO DC Electronics Co., ESL300Z). The single cells were operated at a current density of 150 mAcm^{−2}. To analyze the electrode polarization, electrochemical impedance analysis (EIS) was conducted using a Solartron SI287 and 1260A.

To investigate the impregnated NaCl states after cell operation, the elemental compositions of the electrolytes contained inside the matrices were examined using inductively coupled plasma (ICP) analysis. To confirm the Cl emission during cell operation, the anode outlet gas was soaked in distilled water for 5 h after introducing the reactant gas, and the existence of Cl[−] was confirmed using the ion chromatography (IC) method.

To determine whether the NiO cathode reacts with NaCl, 0.2, 1, and 5 wt.% NaCl-impregnated Ni plates were heat-treated at 650 °C for 100 h in a box furnace, washed 3 times with distilled water, and then dried at 80 °C for 1 h. The crystal structures of the heat-treated samples were investigated by X-ray diffraction (XRD) using a D/Max2400 Rigaku diffractometer with Cu-Kα radiation.

3. Results and discussion

Before the electrochemical performance of the NaCl-impregnated cathode was tested, it was determined whether the NiO cathode reacts with NaCl. 0.2, 1, and 5 wt.% NaCl-impregnated Ni plates were heat treated in air at 650 °C for 100 h. After removing NaCl by washing the plates, XRD analysis was conducted, and the results are presented in Fig. 1. As shown in Fig. 1, the Ni plate is transformed into NiO due to heat treatment in an air atmosphere. In the MCFC, the porous Ni plates transform into a lithiated NiO cathode via lithiation and the oxidation process. If NaCl is doped into NiO, a peak shift phenomenon in the XRD pattern is observed due to the difference in radii between Ni and Na or between O and Cl. However, as shown in the narrow range of Fig. 1(b), a peak shift is not observed. This result indicates that the NiO cathode does not react with NaCl under these experimental conditions. It is expected that introducing NaCl through air does not damage the cathode material in an MCFC stack in a marine atmosphere.

To investigate the NaCl effect on the cell performance, the single cells using 1, 5, and 10 wt.% NaCl-impregnated cathodes and a pure cathode were tested. The single cells were operated at 620 °C. The cell voltages of the single cells using 0, 1, 5, and 10 wt.% NaCl-impregnated cathodes at a current density of 150 mAcm^{−2} after 200 h of operation are presented in Fig. 2. As shown in this figure, the cell voltages increased with increasing amounts of impregnated NaCl. Although we expected the cell voltages to decrease with increasing NaCl amount due to NaCl poisoning of the electrode, the experimental results are not in accord with our expectations.

To understand the cell voltage changes as a function of NaCl-impregnated amount in the cathode, EIS analysis was conducted on single cells using 0, 1, 5, and 10 wt.% NaCl-impregnated cathodes, and these results are presented in Fig. 3. As shown in Fig. 3, the spectra obtained from the EIS analysis of MCFCs have intercepts on the real axis, indicating an ohmic resistance (*R*_o), and, generally, the spectra contain both high- and low-frequency semicircles. It is known that the high frequency semicircles represent the resistances related to the electrochemical reaction and that the low frequency semicircles represent the resistances related to mass transfer [14]. The charge transfer resistance (*R*_{ct}) in the high frequency semicircle and the mass transfer resistance (*R*_{mt}) in the low frequency semicircle can be extracted from the EIS data using an equivalent circuit [15]. The obtained resistances from the single cells using 0, 1, 5, and 10 wt.% NaCl-impregnated cathodes are summarized in Table 2. As shown in Table 2, there are no large

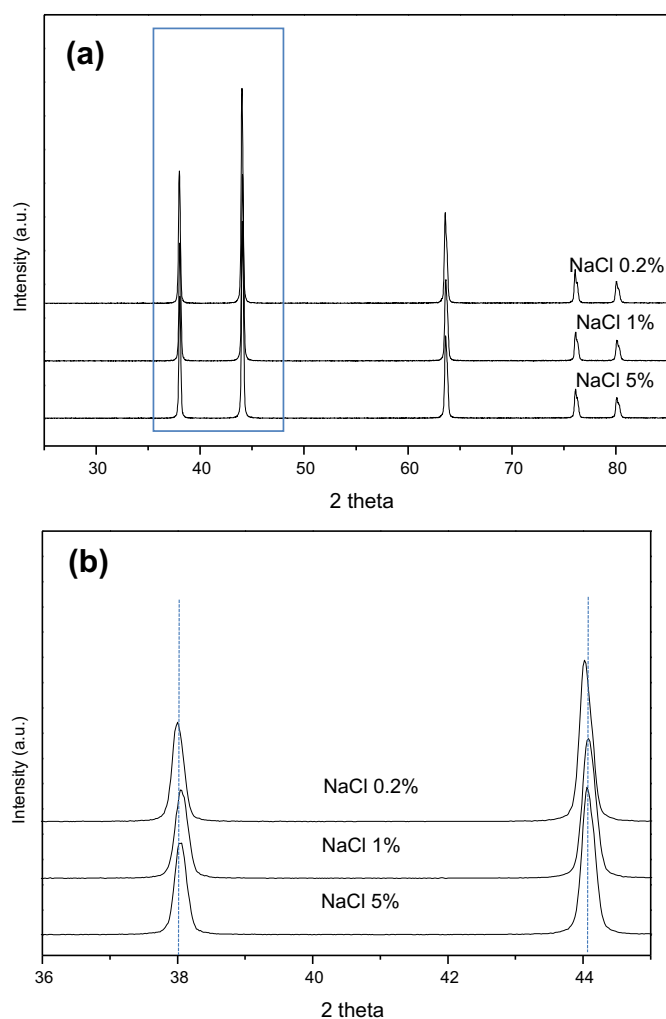


Fig. 1. XRD patterns of the 0.2, 1, and 5 wt.% NaCl-impregnated Ni plates after heat treatment at 650 °C for 100 h (a) broad range and (b) narrow range of 2 theta.

differences among R_{mt} for the 4 cells. R_o and R_{ct} , however, are significantly different among the 4 cells. R_{ct} in cells with 0, 1, 5, and 10 wt.% NaCl-impregnated cathodes are 0.67, 0.67, 0.39, and 0.37 Ωcm^2 , respectively, and R_o in cells with 0, 1, 5, and 10 wt.%

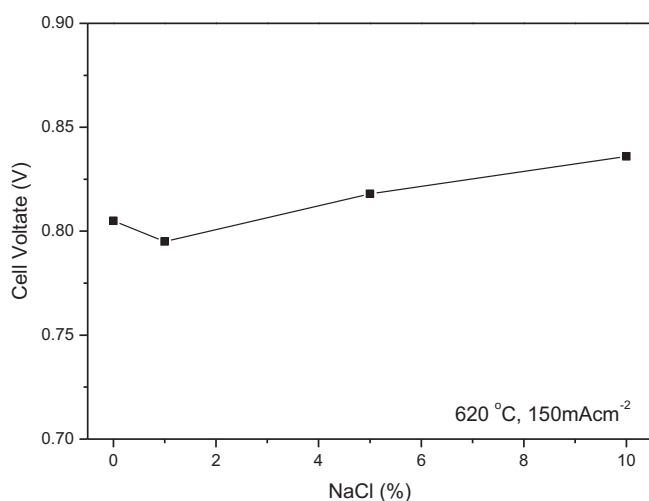


Fig. 2. Cell voltages of the single cells using 0, 1, 5, and 10 wt.% NaCl-impregnated cathodes at a current density of 150 mAcm⁻² and 620 °C.

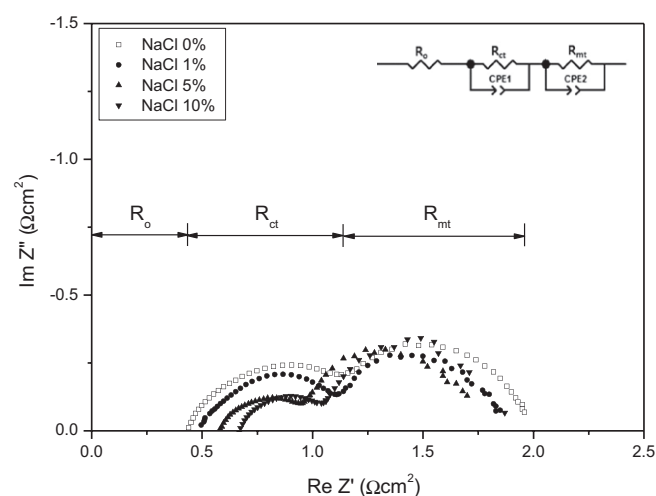


Fig. 3. Nyquist plots obtained for the single cells using 0, 1, 5, and 10 wt.% NaCl-impregnated cathodes at 620 °C.

NaCl-impregnated cathodes are 0.4, 0.49, 0.58, and 0.63 Ωcm^2 , respectively. Thus, R_{ct} decreased and R_o increased with increasing impregnated NaCl amount in the cathode. Although R_o increased with increasing impregnated NaCl amount, the reduction in R_{ct} after NaCl impregnation enhances the cell performance. Because R_{ct} is related to the electrochemical reaction, the R_{ct} reduction after NaCl impregnation indicates that NaCl improves the electrochemical reaction and electrode polarization in the MCFC.

The R_o change after NaCl impregnation indicates a change in the electrolyte property. Thus, the electrolyte composition after cell operation was analyzed using the ICP method. The molar ratios between the metal elements in the electrolyte, such as Li, K, and Na, after operating the single cells using 1 and 5 wt.% NaCl-impregnated cathodes are summarized in Table 3. The molar ratios between Li, K, and Na obtained from calculations, assuming that all impregnated NaCl is dissolved in the electrolyte, are also presented for comparison. As shown in this table, the Na amounts obtained via calculations and experiment are similar for the two single cells. This result indicates that the impregnated NaCl in the cathode is dissolved into the carbonate melts during cell operation. This result also indicates that the Na⁺ ions in NaCl introduced through air in a marine atmosphere are accumulated in the carbonate melts. After cell operation, the amount of Li ions in the electrolyte is greatly reduced. A well-known fact about MCFCs is that the Li ions in the electrolyte react with the Al added into the matrix as a reinforcement aid and with the STS (stainless steel) 316 or 310 stainless steels in the cell frame and current collector, which are the main causes of the Li loss in the electrolyte [16].

There are two approaches to using carbonate electrolytes in MCFCs for applications: one is the utilization of a Li/K-based electrolyte and the other is the utilization of a Li/Na-based electrolyte. It is well known that cell performance with a Li/Na-based electrolyte is higher than that with a Li/K-based electrolyte [17]. Because the ionic conductivity and basicity of a Li/Na-based electrolyte are

Table 2
Obtained resistances of the single cells using 0, 1, 5, and 10 wt.% NaCl-impregnated cathodes.

	R_o (Ωcm^2)	R_{ct} (Ωcm^2)	R_{mt} (Ωcm^2)
NaCl 0%	0.40	0.67	0.88
NaCl 1%	0.49	0.67	0.75
NaCl 5%	0.58	0.39	0.79
NaCl 10%	0.63	0.37	0.87

Table 3

Comparison between calculated and experimental results of Na molar ratios in the electrolytes of the single cells using 1 and 5 wt.% NaCl-impregnated cathodes.

	Calculated results before cell operation	*Calculated results after cell operation	Experimental results
	Li:K:Na	Li:K:Na	Li:K:Na
NaCl 1%	69.7:29.9:0.5	53.5:29.9:0.5	48.3:29.9:0.7
NaCl 5%	68.3:29.3:2.4	52.5:29.3:2.4	55.9:29.3:2.3

*When using a 10 wt.% Al fiber reinforced matrix, the Li consumption is determined from the reaction between Al in the matrix and Li in the electrolyte.

higher than those of a Li/K-based electrolyte [18], the improvement in the ohmic resistance and cathode polarization enhances the cell performance when using a Li/Na-based electrolyte instead of a Li/K-based electrolyte. According to the analysis by Morita et al. [17], the anode polarization is not changed when using a Li/Na-based electrolyte instead of a Li/K-based one. To confirm whether the Na content produces a positive effect on the cathode reaction, symmetric cell tests were conducted using a conventional cathode and a 3 wt.% NaCl-impregnated cathode, and the results are presented in Fig. 4. As shown in this figure, the resistance in the high frequency arc for the symmetric cell using a 3 wt.% NaCl-impregnated cathode is much smaller than that using a conventional cathode. This result clearly shows that the Na content reduces the cathode polarization. Additionally, as shown in Fig. 2 and Table 2, the cell performance increased and the charge transfer resistance decreased with increasing impregnated NaCl amount. Thus, the O_2 solubility in the electrolyte also increased with increasing Na concentration, which improves the cathode reaction and enhances the cell performance.

According to Morita et al. [17], R_o is reduced in the Li/Na electrolyte due to fast-ion conductivity. In this experiment, however, R_o increased with increasing Na concentration in the electrolytes for both the single cell tests and symmetric cell tests. This result is most likely due to the Na_2CO_3 high corrosion of STS 316 or 310 stainless steel, which constitute the cell frame and current collector of the cathode. According to the report by Lim et al. [19], a Li/Na-based electrolyte induces severe corrosion of STS 316 or 310 stainless steels in the temperature range of 500–580 °C. This corrosion phenomenon is dramatically reduced in the temperature range of 600–650 °C. It is known that severe corrosion of STS 316 or 310 stainless steel caused by a Li/Na-electrolyte during pre-treatment obscures the measurement of the cell's performance.

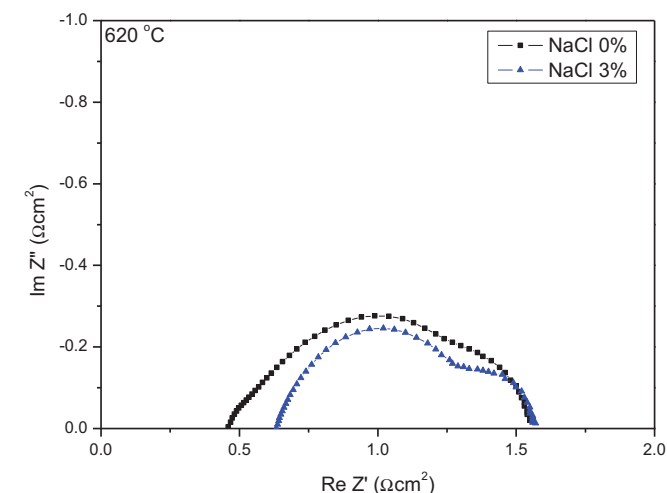


Fig. 4. Nyquist plots in symmetric cells using a non-impregnated cathode and a 3 wt.% NaCl-impregnated cathode at 620 °C.

Fig. 5 shows the surfaces of cell frames after the symmetric cell operation of a conventional cathode and of a 3 wt.% NaCl-impregnated cathode. As shown in this figure, the surface of the cell frame of the symmetric cell using a 3 wt.% NaCl-impregnated cathode is more damaged than that using a conventional cathode. In this experiment, no action is taken to prevent STS corrosion. Thus, these results indicate that the corrosion of STS 316 or 310 stainless steel, which occurred due to Na_2CO_3 formation during the pretreatment process after Na was dissolved in the electrolyte, causes the increase in R_o . It, however, is expected that this corrosion does not affect the application of MCFC stacks in a marine atmosphere because the inflow of NaCl into the MCFC stacks through air begins after reaching a temperature of 600–650 °C.

We know that the Na of NaCl is dissolved and accumulated in carbonate melts during cell operation and that this Na enhances cell performance by improving the cathode polarization. So where is the Cl ion of NaCl, and what is the effect of Cl on the MCFC? To answer these questions, Cl^- ions were also analyzed using the IC method. The Na:Cl molar ratios in the electrolytes of single cells using 1 and 5 wt.% NaCl-impregnated cathodes are 5:1 and 4:1, respectively. Approximately 80 at.% of the Cl^- ions disappear. To determine where the Cl^- ions go, the anode outlet gas was investigated because Cl^- is a negative ion. It is predicted that a negative Cl^- ion dissolved in the carbonate melts moves to the anode due to the voltage and concentration gradients. The anode outlet gas line in the single cell using a 5 wt.% NaCl-impregnated cathode was soaked in a water bath for 5 h after introducing the reactant gas,

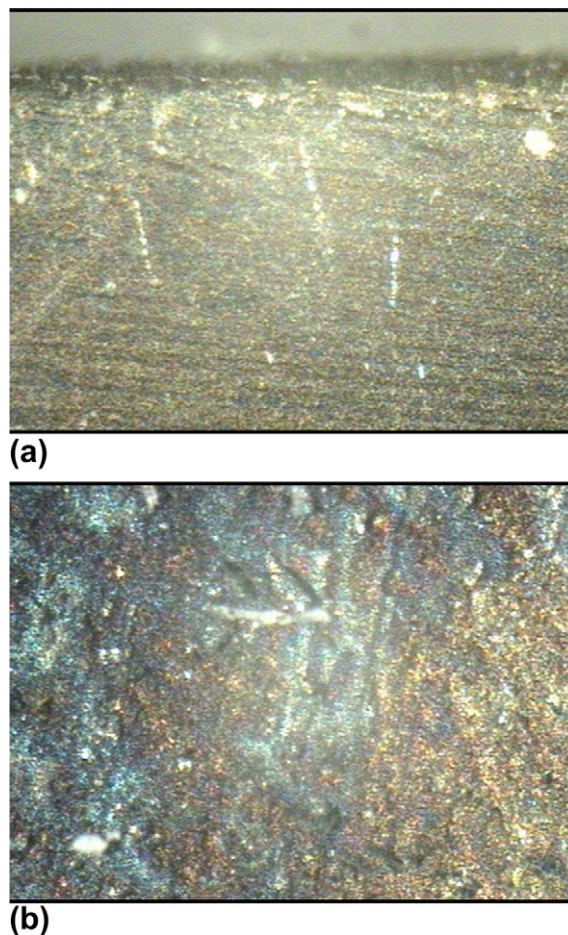
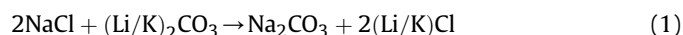


Fig. 5. Images of cell frame surfaces in a wet-seal area after cell operation of (a) a non-impregnated cathode and (b) a 3 wt.% NaCl-impregnated cathode.

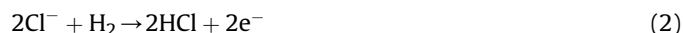
and this water was analyzed using the IC method. Cl^- ions were detected at 92.6 ppm. Although the mass balance of Cl^- ions is difficult, this result verifies that some Cl^- ions dissolved in the carbonate melts are emitted into the anode outlet. This result also indicates that the Cl^- ions transported to the anode side react with H_2 and form HCl. The formed HCl is apparently emitted out of the cell with the anode outlet gas.

The HCl effect on MCFC stacks has attracted a lot of attention because the several gases recommended as alternative fuels for H_2 , such as coal gas, biogas, etc., contain many contaminants, such as H_2S , HCl, HF, and NH_3 [20]. For example, a coal gas that has not been cleaned up contains approximately 3–150 ppm of HCl [20]. As is well known, HCl is a strongly corrosive and toxic gas. HCl vapor has a high corrosion potential when in contact with metal components. According to the report by Watanabe et al. [10], however, the addition of 10 ppm HCl has no effect on the cell voltage over several thousand hours. Nevertheless, long-term exposure to HCl has harmful effects because this exposure can lead to the severe corrosion of utilities. Consequently, it has been suggested that the HCl level in MCFC feedstock must be kept below 1 ppm [21].

The summary of the reaction mechanism of NaCl introduced into the cell through air is presented in Fig. 6. As shown in this figure, the NaCl introduced into the cell is dissolved in the carbonate melts according to the following equation.



Then, the Na^+ ion is in the electrolyte, but the Cl^- ion is transported by the electrochemical driving force to the anode. The Cl^- ion transported into the anode reacts with H_2 according to the following equation.



The formed HCl is emitted out of cell with the anode outlet gas. The accumulated Na^+ ions in the electrolyte produce a positive effect, such as improving the cathode polarization and enhancing the cell performance. The emitted HCl, however, produces a negative effect, such as corrosion of the utilities including the cell frame, pipe line, separator or furnace.

The actual NaCl amount introduced into the cell in a marine atmosphere has to be determined because it helps the understanding of the actual NaCl impurity effect in a marine atmosphere. Thus, the amount of Na^+ ions accumulated in the carbonates is calculated for different operating times and different concentrations of Cl^- ions emitted into the anode outlet. According to Hong et al. [22], the daily average concentration of sea-salt particles is approximately 8.5 ug m^{-3} along the Jeju coast of Korea. According to Jaarsveld and Klimov [23], the yearly average concentration of PM (particulate matter) should not be greater than 40 ug m^{-3} , and the daily average concentration should not be larger than 50 ug m^{-3} . Of the various PMs, sea-salt accounts for approximately 20%,

Table 4

Concentration of accumulated Na^+ ions in the electrolyte as a function of increasing operating time and of seawater particle concentration in a marine atmosphere obtained from calculations.

Operating time (h)	Seawater particle concentration in a marine atmosphere (ug m^{-3})							
	5	10	30	50	80	100	300	500
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
500	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.04
1000	0.00	0.00	0.00	0.01	0.01	0.01	0.04	0.07
3000	0.00	0.00	0.01	0.02	0.03	0.04	0.13	0.22
5000	0.00	0.01	0.02	0.04	0.06	0.07	0.22	0.36
10,000	0.01	0.02	0.05	0.08	0.12	0.15	0.45	0.75
20,000	0.02	0.03	0.10	0.16	0.26	0.33	0.97	1.61
40,000	0.04	0.08	0.23	0.39	0.62	0.78	2.29	3.76

according to the authors. However, according to Jaarsveld and Klimov [23], the maximum concentration of sea-salt in the Netherlands in 2004 was 538 ug m^{-3} . Based on these data, the Na^+ mol% accumulated in the electrolyte as a function of operating time and of sea-salt concentration in a marine atmosphere and the emitted Cl^- amount as a function of sea-salt concentration are calculated. The considered range of sea-salt particle concentration is $5\text{--}500 \text{ ug m}^{-3}$, and it is assumed that the sea-salt particles are 100% NaCl. The utilizations of fuel and oxygen (U_f and U_o) are fixed at 0.4. For the calculations, it is assumed that NaCl that has entered into the cell is dissolved in the electrolyte, that all Na^+ ions are accumulated in the electrolyte, and that 80% of the Cl^- ions are emitted as a form of HCl. The amount of Na^+ ions accumulated in the electrolyte as a function of sea-salt particle concentration and operating time are summarized in Table 4. As shown in this table, when 10 ug m^{-3} of NaCl particles are introduced, which is a similar value to the daily average concentration at Jeju in Korea, the concentration of Na^+ ions accumulated in the electrolyte is only 0.08 mol% after 40,000 h of operation, which is the targeted operation time of the MCFC stack. This value is very small compared with our experimental results, where the Na^+ concentration in the electrolyte is 0.5 mol% for a 1 wt.% NaCl impregnation in the cathode, as shown in Table 3. Even when introducing a high concentration, 500 ug m^{-3} of NaCl, into the cell, the calculated concentration of Na^+ accumulated in the electrolyte is just 3.76 mol%, which is slightly higher than the experimental Na^+ concentration in the electrolyte for a 5 wt.% NaCl impregnation in the cathode. Although the Na^+ inflow into the MCFC stack produces a positive effect on the cell performance, it is expected that there are no Na effects on the cell performance during an actual marine application of MCFCs because of the very low level of impurities.

The emitted HCl concentrations from the anode outlet with increasing sea-salt particle concentration in a marine atmosphere are summarized in Table 5. As shown in this table, even when introducing a high concentration, 500 ug m^{-3} of NaCl, into the cell, the emitted HCl concentration is just 0.55 ppm. This result indicates that

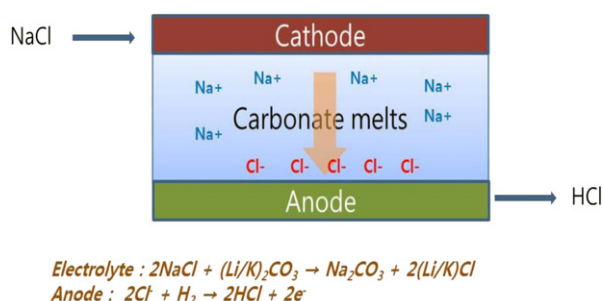


Fig. 6. Reaction mechanism of an NaCl impurity introduced into an MCFC.

Table 5

Emitted HCl concentration in an anode outlet gas as a function of seawater particle concentration in a marine atmosphere obtained from calculations.

Seawater particle concentration in a marine atmosphere (ug m^{-3})	HCl concentration in an anode outlet gas (ppm)
5	0.01
10	0.01
30	0.03
50	0.06
80	0.09
100	0.11
300	0.33
500	0.55

the HCl value is too small to damage the utilities by corrosion because the allowable concentration of HCl is 1 ppm, as mentioned above.

4. Conclusions

For marine applications of MCFCs, the effects of NaCl, a main component of seawater, are investigated. The NaCl impurities introduced into the cell through air are dissolved in the electrolyte, the Na⁺ ions are accumulated in the electrolyte, and some of the Cl[−] ions are emitted into the anode outlet as HCl. It is expected that the accumulated Na⁺ ions produce a positive effect on the cell performance and that the emitted HCl causes a severe corrosion of the utilities. According to the calculations of the accumulated Na⁺ ion concentrations in the electrolyte and of the emitted HCl from the anode, assuming that the introduced sea-salt particle concentration in a cell is 5–500 $\mu\text{g m}^{-3}$ based on actual concentrations of sea-salt in the marine atmospheres of Jeju and the Netherlands, it is expected that the emitted HCl does not cause severe corrosion because the emitted HCl concentration is too low, less than 1 ppm for even 500 $\mu\text{g m}^{-3}$ of sea-salt. A 1 ppm HCl concentration is allowable in MCFCs for applications.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.jpowsour.2013.01.005>.

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